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Aortic Bifurcation and Its Relationship to the Lumbosacral Spine: Insights from MRI Imaging

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ABSTRACT

Background

The anatomical relationship of the aortic bifurcation to the lumbar vertebrae is crucial in vascular, orthopedic and neurosurgical procedures. Variations in the aortic bifurcation location can impact vascular surgeries, lumbar spine interventions and diagnostic imaging interpretations. However, most anatomical data are based on Western populations and there is a lack of MRI-based studies focusing on the Nepali population. Given the rising burden of vascular diseases and spinal disorders in Nepal, understanding these anatomical variations is essential for improving clinical outcomes. This study aims to use MRI to determine the level of aortic bifurcation in nepali population.

Methods

A cross-sectional study was conducted in the Department of Radiology, Bharatpur Hospital from September 2024 to March 2025. 200 patients presenting for MRI above 20 years of age in the radiology department were taken as cases. The level of the aortic bifurcation was analyzed using axial and sagittal midline MRI images. These positions were documented in relation to either the upper , mid or lower level of the nearby vertebral body or the adjacent intervertebral disc space.

Results

Out of 200 patients aortic bifurcation was seen in most cases at the level of L4 vertebral body.

Conclusions

In the current study, the aortic bifurcation is predominantly observed at the level of the L4 vertebra, aligning with findings from most of the earlier research.

Keywords: aortic bifurcation; lumbar vertebra; Nepali population; magnetic resonance imaging.

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INTRODUCTION

The aortic bifurcation is a vital anatomical point where the abdominal aorta splits into the right and left common iliac arteries.[1] This bifurcation generally occurs at the level of the L4 vertebral body, although some anatomical variations can be found between L3 and L5 [2, 3]. In elderly individuals, the aortic bifurcation tends to shift downward due to osteoporosis and degeneration of the intervertebral discs.[4] These variations are particularly important in fields such as vascular surgery, neurosurgery, and orthopedics, especially during lumbar spine surgeries and treatments for aortic aneurysms or peripheral arterial diseases.[3,5] In clinical settings, MRI (Magnetic Resonance Imaging) is essential for pinpointing the exact location of the aortic bifurcation, which is vital for surgical planning and enhancing diagnostic precision.[6] However, the majority of anatomical research on the positioning of the aortic bifurcation primarily focuses on Western populations, with scarce information available regarding the Nepali population. Considering the increasing prevalence of vascular diseases and spinal issues in Nepal, it is important to comprehend the anatomical connection between the aortic bifurcation and lumbar vertebrae in the local demographic to enhance clinical outcomes. This research will offer anatomical data specific to Nepal and the results of this research will offer significant reference information for surgeons, radiologists, and clinicians in Nepal, leading to improved precision in vascular and spinal procedures,will support the optimization of surgical methods, diminish complications, and enhance patient results.

METHODS

This study was conducted in the Department of Radiology, Bharatpur Hospital from September 2024 to March 2025 after obtaining ethical clearance from the Institutional Review Committee (IRC) of Bharatpur Hospital. Inclusion criteria were 1.Adults > 20 years who have undergone MRI imaging of the abdomen or lumbosacral spine. 2. MRI scans with sufficient resolution and clarity to accurately visualize the aortic bifurcation and lumbar vertebrae.3. Patients who have undergone MRI for diagnostic purposes related to abdominal or spinal conditions. Exclusion criteria were 1. MRI scans with motion artifacts, poor resolution or incomplete visualization of the aorta and lumbar vertebrae.2 .History of Major Abdominal or aortic vascular Surgery. Patients who have undergone surgeries that may alter the normal anatomy of the aorta. 3.Severe Degenerative or Destructive Spinal Pathologies. 4. Cases with extensive spinal deformities, severe scoliosis, or vertebral destruction that might alter the normal vertebral landmarks. 5. Pregnant Women:excluded to avoid potential biases due to pregnancy-related anatomical changes in vascular structures.

MRI examinations were performed using a Siemens Magnetom vida 3 tesla MRI scanner. The standard institutional protocol included sagittal T1-weighted and T2-weighted spin echo sequences, STIR sequences, coronal STIR, as well as axial T1, T2, and STIR sequences. Additionally, an axial T2-weighted SPACE sequence was acquired to precisely evaluate the level of the aortic bifurcation. Whole-spine T2-weighted sagittal imaging was obtained to assess and count the cervical, thoracic, lumbar and sacral vertebrae. Following image acquisition, axial and sagittal datasets were reviewed on the console. The abdominal aortic bifurcation into the right and left common iliac arteries was identified on axial slices and confirmed in sagittal view to determine its craniocaudal position relative to the lumbar vertebrae. The bifurcation level was documented as occurring at the L3, L4, or L5 vertebral bodies, L3–L4 or L4–L5 intervertebral discs. Each vertebral body level was further divided into upper, middle and lower thirds for more detailed localization. Data were collected using a structured proforma and analyzed with the Statistical Package for the Social Sciences (SPSS).

RESULTS

A total of 200 patients were included in the study, consisting of 88 males and 112 females. The age of

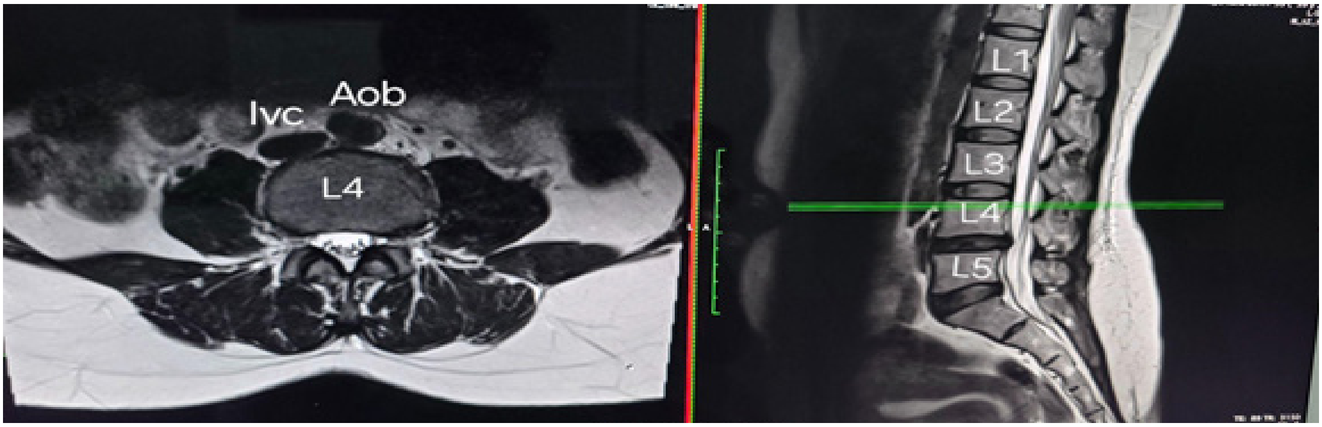

Figure 1: Axial and sagittal MRI of Lumbosacral spine , aortic bifurcation at the level of upper border of L4 vertebra. Aob: aortic bifurcation, Ivc: Inferior venecava, L1,L2,L3,L4 and L5 : Lumbar vertebral bodies.

the study population ranged from 21 to 80 years. The highest distribution of cases was observed in the 31–40 year age group (n=62), whereas the lowest frequency was noted in the 71–80 year age group (n=9).

Table 1.Age distribution. (n=200)

Age (years)	Male (n)	Female (n)	Total (n)	Percentage (%)
21-30	14	12	26	13
31-40	25	37	62	31
41-50	22	24	46	23
51-60	17	27	44	22
61-70	5	8	13	6.5
71-80	5	4	9	4.5

The aortic bifurcation was most commonly observed at the L4 vertebral body (n = 111), followed by the L3–L4 intervertebral disc (n = 52), L3 vertebral body (n = 21), L4–L5 disc (n = 13), and L5 vertebral body (n = 3). A weak but statistically significant correlation was found between age and vertebral level (Spearman's rs = 0.15, p = 0.033), indicating a slight caudal migration of the bifurcation with increasing age.

However, one-way ANOVA did not reveal significant differences in mean age across the different vertebral levels (p = 0.13). Scatter plot evaluation indicated only a subtle upward trend, with regression analysis estimating that each additional year of age corresponded to a downward shift of approximately 0.01 vertebral units (equivalent to one lumbar level per ~100 years). Overall, the findings indicate that while age-related caudal displacement of the aortic bifurcation is statistically detectable, the effect size is small and not clinically meaningful.

Table 2. Distribution based on vertebral level (n=200)

Vertebral level of bifurcation	Frequency (%)
L3 Vertebra	21(10.5)
L3-L4 Disc	52(26)
L4 vertebra	111(55.5)
L4-L5 Disc	13(6.5)
L5 vertebra	3(1.5)

The relationship of the aortic bifurcation to the upper, middle and lower thirds of the vertebral bodies and adjacent disc spaces was also assessed. The bifurcation was most frequently located at the upper third of the L4 vertebral body (n = 54). Most bifurcations were clustered around the L4 vertebral body and L3–L4 disc, together accounting for over 70% of cases 90 (Table 3).

In males (n = 88), the aortic bifurcation was most frequently located at the L4 vertebral body (n = 50), followed by the L3–L4 disc (n = 24). In females (n=112), the most common sites were similarly the L4 vertebral body (n = 61) and the L3–L4 disc (n = 28). Statistical analysis revealed no significant sex-related differences (Mann–Whitney U test, p = 0.72; Chi-square test, p ≈ 0.60). Correlation analysis demonstrated the correlation between sex and vertebral level was negligible (r ≈ –0.05) indicating

Table 3: Distribution based on upper, mid and lower third of vertebral bodies or to disc spaces

Vertebral level	Frequency(n)	Percentage
Upper L3	2	1
Mid L3	5	2.5
Lower L3	14	7
L3-L4 disc	52	26
Upper L4	54	27
Mid L4	38	19
Lower L4	19	9.5
L4-L5 Disc	13	6.5
Upper L5	2	1
Mid L5	1	5

a very weak negative relationship, which is likely not meaningful. This suggests that neither age nor gender strongly influences the vertebral level in this dataset.

DISCUSSION

In most anatomical references, including Gray's Anatomy[7], the aortic bifurcation is described at the L4 vertebral level. In our study of 200 patients, the bifurcation was most frequently observed at L4 (55%). Most bifurcations were clustered around the L4 vertebral body and L3–L4 disc, together accounting for over 70% of cases. A gradual decline in frequency was observed cranially toward L3 and caudally toward L5, with only a small minority extending below the L4–L5 disc. These findings reinforce the classical anatomical description that the abdominal aorta most commonly bifurcates at or near the L3–L4 disc level. These findings closely align with those of Lee et al.[3] who reported the mean bifurcation at the upper half of L4 with 83% occurring at L4, Chithriki et al.[6] who found 67% at L4, with the remainder distributed between L3 and L5 Marchi et al.[8] in MRI based study found aortic bifurcation was generally ahead of L4 (52%) and less frequently at L3-L4 (28%) and L4-L5 (18%).In contrast, Bera et al.[9] in a cohort of cervical malignancy patients, reported the bifurcation most often at the L3–L4 disc. Other studies also highlight factors influencing this variation. Kornreich et al.[10] observed the mean bifurcation at the lower L4 level and showed that age explained 19% of positional changes, with a descent of 13.5% of vertebral height per decade, attributed to osteopenia and disc degeneration. Kawahara et al.[11] 1996 reported that the level of termination of great vessels shifted significantly downwards with age and this observation is justified by the loss of overall height due to dehydration of intervertebral discs as well as osteoporosis in the elderly. Rai et al[12], reported that almost 71% of patients' aortic bifurcation was above L4–L5 intervertebral disc level. The study was however conducted among patients with cervical cancer who underwent radiotherapy. Population-based differences have also been noted. In thai population,Khamanarong et al.[4] reported the bifurcation at L4 in 70.1%, while Ogeng et al.[13] observed L4 as the most frequent site in a Kenyan population. Lakchayapakorn et al.[2] in a study in Chinese population , similarly reported L4 as the most common level (63%), predominantly at the middle third, with no significant sex differences. Postural influence was demonstrated by Vaccaro et al.[14]and Bečulić et al.[15] who both showed a slightly higher bifurcation in the prone compared to the supine position. A meta-analysis by Panagouli et al.[16] involving 3537 specimens, further reinforced these findings, with L4 being the most common site (42.2%), particularly the upper third when subdivided. In a study by Barrey et al[17] the level of aortic bifurcation was L3-L4 in 21.9% (32 of 146), L4 in 63.7% (93 of 146), and L4-L5 in 14.4% (21 of 146) of patients. In cadaver based study by Pirro et al[18] the aortic bifurcation was most frequently at the L5 level (n=21, 50%). These findings of low aortic bifurcation may be due to old age of study groups . This lower level of aortic bifurcation in elderly may be due to elongation and tortuosity of aorta with age and age related changes in lumbar spine such as decrease in disc and vertebral height Our analysis did not identify a statistically significant relationship between sex and the vertebral level of the aortic bifurcation. This observation is supported by comparable findings from Molinares et al.[19], Bečulić et al.[15], and Goyal et al.[20]. Nevertheless, a clear consensus within the literature is lacking, as demonstrated by the contradictory results of Kornreich et al.[10] who observed a more inferior bifurcation in female subjects.

Taken together, our findings, in agreement with most published series, confirm that the aortic bifurcation is most frequently located at the L4 vertebral body.

Proportion of aorta that terminate at the level of L4 in different populations		
Population	**Proportion terminating at L4**	**Reference**
American	67	Chithriki et al , 2002
Chinese	63	Lakchayaparkorn et al, 2008
Kenyan	73.6	ogeng'o et al 2014
Korean	83	lee et al 2004
Thai	70.1	Khamanarong et al., 2009
Nepalese	55.5	current study

Nonetheless, considerable variation exists, extending from L3 to L5, and this may be influenced by age, posture, and population characteristics—factors important to consider in surgical and interventional planning.

Analysis of the cohort in our study revealed several key patterns in aortic bifurcation: 1.Typical pattern: Approximately 80% of bifurcations were located between the L3–L4 disc and the L4 vertebral body, consistent with standard anatomical descriptions. 2.High bifurcation: In 21 patients (≈10%), the bifurcation occurred as high as the L3 vertebral body. Recognition of these high variants is clinically important, particularly for left-sided renal or adrenal surgical exposure, as the aortic segment terminates sooner than anticipated. 3. Low bifurcation: In 16 patients (≈8%), the bifurcation extended to the L4–L5 disc or even the L5 vertebral body.

Clinical implications obtained from our study: Preoperative imaging is essential, as nearly one in five patients exhibits bifurcation levels that deviate from the standard pattern. High bifurcations may increase the risk of inadvertent low aortic clamping, whereas low bifurcations may predispose to iliac vessel injury if the aortic segment is assumed to be longer. Although age appears to shift the bifurcation caudally ,interventional planning should rely on imaging rather than age-related assumptions.

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CONCLUSIONS

Our study confirms that the aortic bifurcation most commonly occurs at the L4 vertebral body, in agreement with classical anatomical descriptions and the majority of previous imaging-based studies. However, significant variation was observed, with bifurcation levels extending from the upper third of L3 to the middle third of L5. Age-related changes, posture and population differences contribute to this variability. Sex did not appear to influence the bifurcation level in our cohort. These findings emphasize the importance of precise preoperative imaging, particularly for vascular, spinal, and interventional procedures in the lumbosacral region, where knowledge of anatomical variations of the aortic bifurcation is critical for safe and effective surgical planning.

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